DIMENSIONAL STABILITY CONSIDERATIONS FOR CRYOGENIC METALS

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This presentation is a report on work performed as part of an effort to identify and where possible separate out some of the factors that contribute to dimensional stability in cryogenic wind tunnel models. Small dimensional changes in wind tunnel models being tested at high Reynolds number become quite significant because of the more stringent requirements on model aerodynamic coordinates and surface smoothness.

Initial problems were encountered with two-dimensional models made of 15-5 PH stainless steel, which warped significantly after being subjected to cryogenic testing in the 0.3-Meter Transonic Cryogenic Tunnel (TCT). Subsequently, an effort was undertaken to investigate the mechanisms that could cause model warpage during cryogenic testing.

The two basic mechanisms that can lead to warpage are (1) metallurgical structural instability in which one phase transforms partially or fully into a second phase which has a different crystal structure and volume, and (2) deformation due to the creation, or relief, of unbalanced induced or residual stresses. In the case of the 15-5 PH airfoils, it is highly probable that metallurgical instability was responsible for most of the observed warpage.

A major point to be made is that even in metallurgically stable materials, cryogenic cycling can alter the residual stress system and thus lead to dimensional changes. It is often possible, however, to achieve dimensional stability by carrying out a number of cryogenic cycles such that the stress system is stabilized and no warpage occurs during subsequent cycles.

A particular specimen configuration was established for use in the systematic evaluation of the factors influencing warpage and is shown in figure 1. Preliminary studies of a specimen made of VASCOMAX 200 suggest the possibility of manipulating the stresses in the surface layers by appropriate combinations of milling and grinding steps. This opens up the possibility of correcting or establishing the required surface profile of an airfoil. This behavior is illustrated in figures 2 and 3 which show the results of deflection measurements made after each machining step.

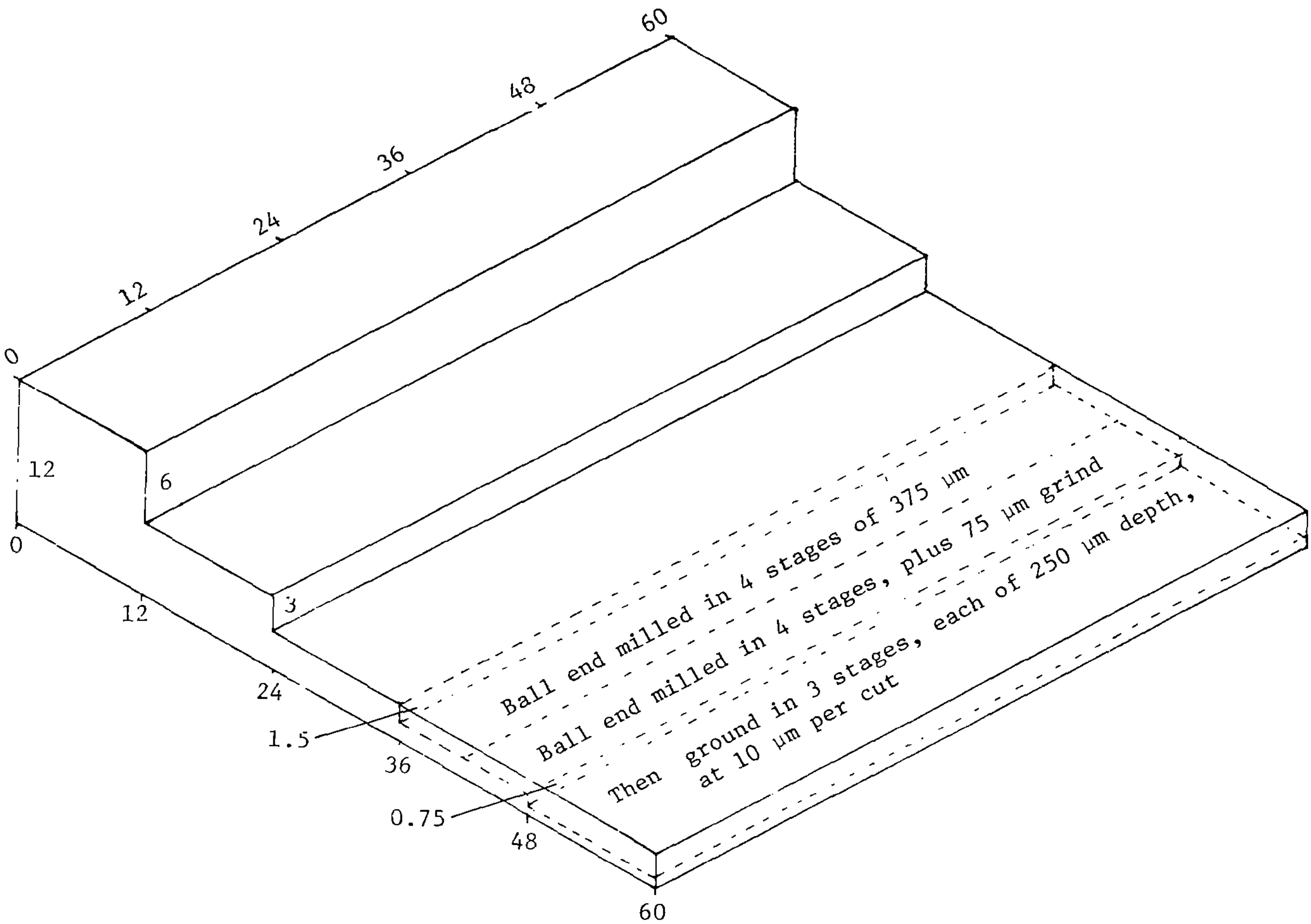

Figure 1.- Recommended configuration of proposed standard specimen for warpage experiments. (Dimensions in millimeters.)

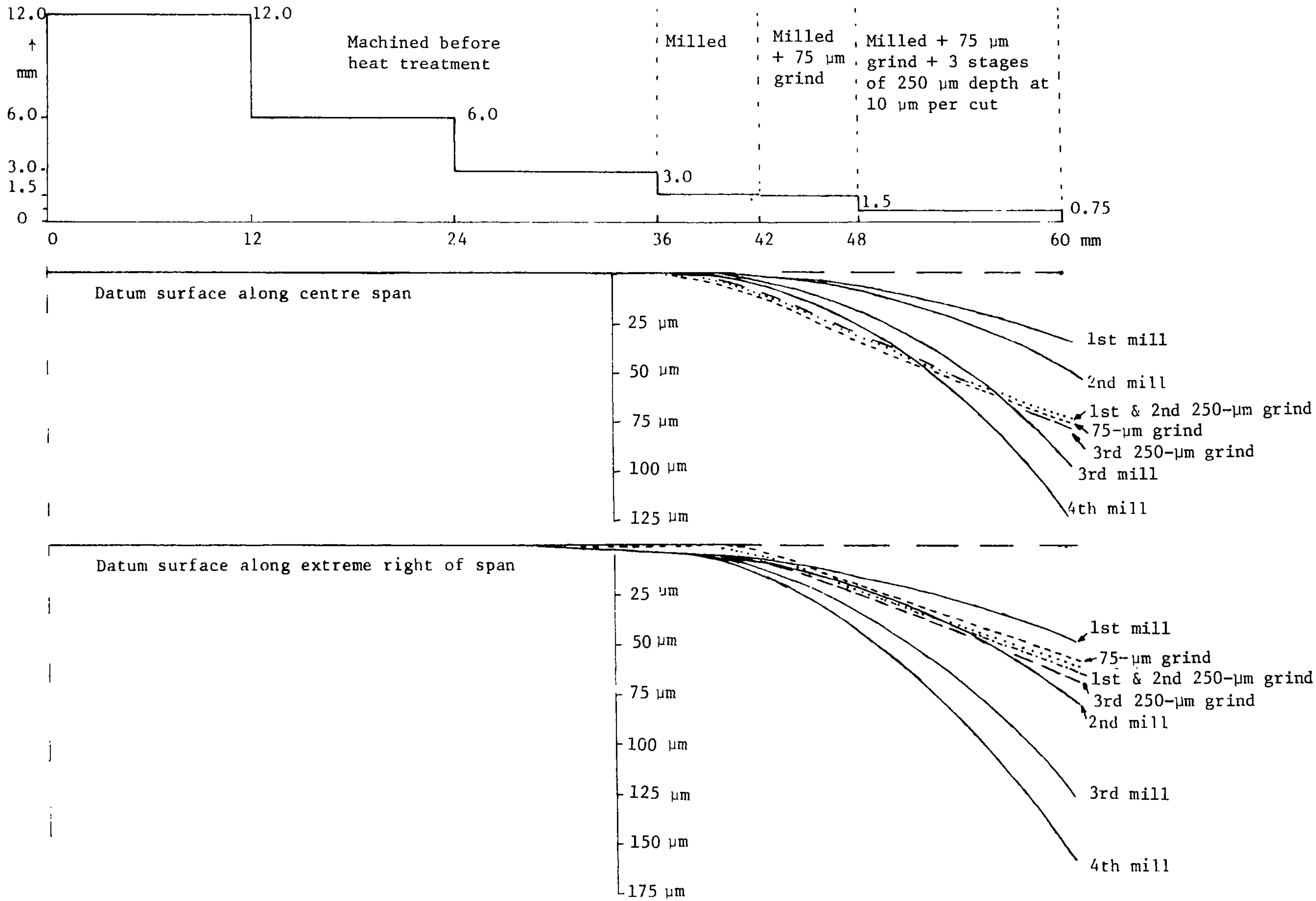

Figure 2.- Longitudinal profiles of machined Vascomax 200.

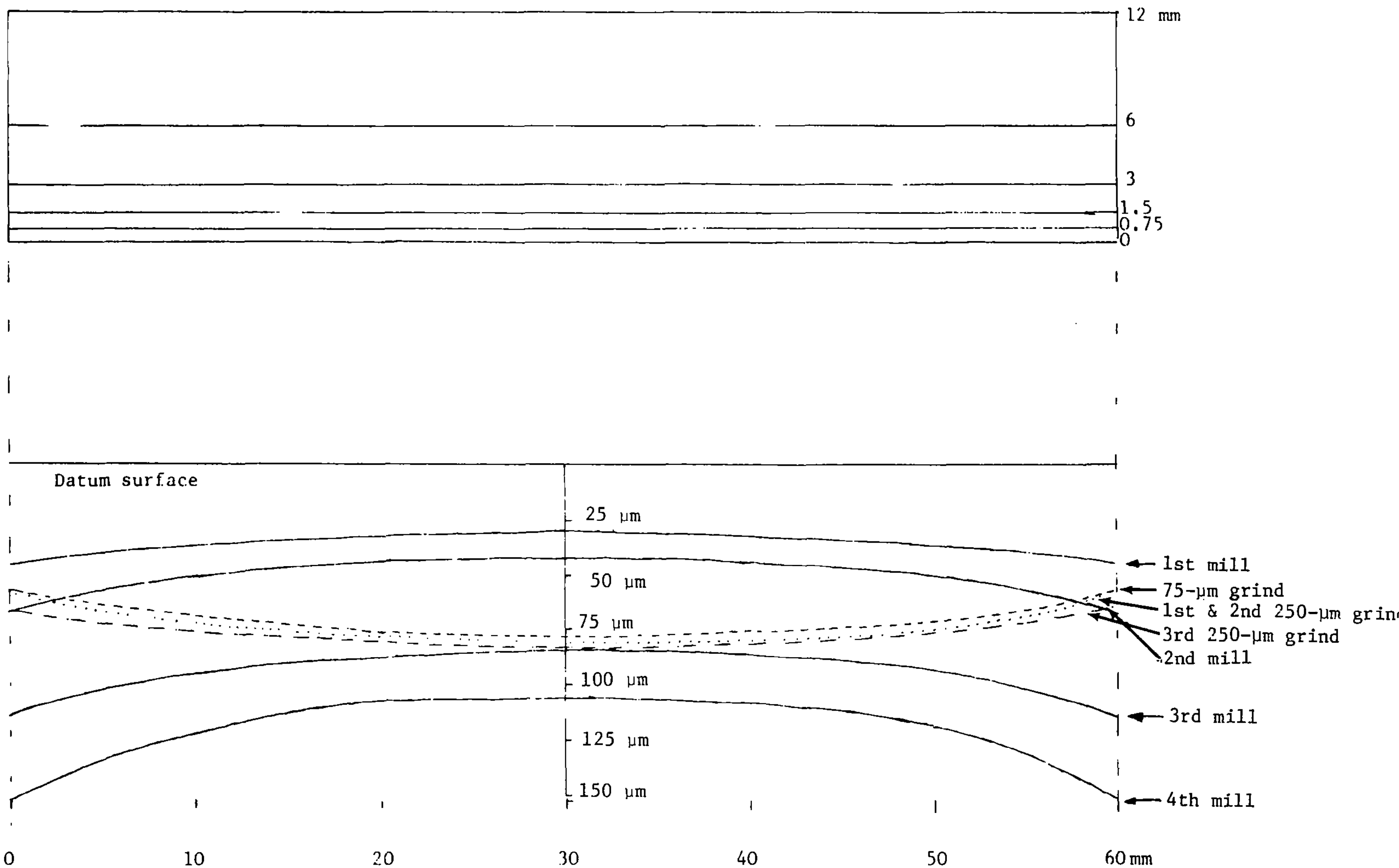

Figure 3.- Transverse profiles of machined Vascomax 200.